



RESEARCH DEPARTMENT



REPORT

Probability levels of sound interference between programme areas

R. Walker, B.Sc.(Eng.)

PROBABILITY LEVELS OF SOUND INTERFERENCE BETWEEN PROGRAMME AREAS

R. Walker, B.Sc.(Eng.)

Summary

Sound insulation must be provided between any two programme areas which are near to or adjacent to each other. For economic reasons, this insulation ideally must be no more than is necessary to reduce the interference from one area to the other to an acceptably low level.

To determine the minimum necessary sound insulation requires a knowledge of the maximum sound pressure level on the source side of the partition, and the level to which this must be reduced on the receiving side. However, neither of these can be determined absolutely. The source sound pressure level is a statistical function of time and the level to which it must be reduced depends on the background noise level in the receiving area.

The object of this report was to combine the results obtained from a large number of measurements of source sound pressure levels with the results obtained from a study of the masking effect of background noise. This produced a statistical evaluation of the probability of interference criteria being exceeded under a number of different conditions.

Using the earlier criterion, that the insulation was sufficient if the peak sound pressure level of the source area was reduced to be equal to the maximum permitted background noise level (in the same frequency bands) of the receiving area, it was found that interference could be perceptible for up to 22% of the time and disturbing for over 4% of the time under certain conditions.

Issued under the authority of



Research Department, Engineering Division,
BRITISH BROADCASTING CORPORATION

Head of Research Department

August 1978
(PH-199)

PROBABILITY LEVELS OF SOUND INTERFERENCE BETWEEN PROGRAMME AREAS

Section	Title	Page
	Summary	Title Page
1.	Introduction	1
2.	Amplitude probability distribution of sound pressure levels	1
3.	Effects of masking	3
4.	Calculations of the percentage of time for which the critical levels are exceeded	4
5.	Results	4
6.	Conclusions	6
7.	References	6
	Appendix 1 – Worked Examples	7

© BBC 2004. All rights reserved. Except as provided below, no part of this document may be reproduced in any material form (including photocopying or storing it in any medium by electronic means) without the prior written permission of BBC Research & Development except in accordance with the provisions of the (UK) Copyright, Designs and Patents Act 1988.

The BBC grants permission to individuals and organisations to make copies of the entire document (including this copyright notice) for their own internal use. No copies of this document may be published, distributed or made available to third parties whether by paper, electronic or other means without the BBC's prior written permission. Where necessary, third parties should be directed to the relevant page on BBC's website at <http://www.bbc.co.uk/rd/pubs/> for a copy of this document.

PROBABILITY LEVELS OF SOUND INTERFERENCE BETWEEN PROGRAMME AREAS

R. Walker, B.Sc.(Eng.)

1. Introduction

Wherever two or more programme areas are adjacent or near to each other, sound insulation has to be provided between the areas to reduce the interference from one area to the other to an acceptable level. Although it is theoretically possible to install sufficient insulation effectively to completely isolate each area, this approach would be totally unreasonable and extremely expensive. A wiser approach is necessary to estimate the minimum acceptable insulation needed in each case. To do this requires a knowledge of the sound pressure level in the source area and the level to which it must be reduced in the receiving area.

The two factors which must be considered are the statistical distribution of sound pressure levels in the source area and the extent to which any interference in the receiving area is masked by that area's own background noise level. Previous work¹ assumed that the insulation was sufficient if the peak sound pressure level of the source area (usually measured in 1/3rd octave bands) was reduced to the level of the maximum permitted background noise criterion (in the same frequency bands) of the receiving area.

This insulation criterion has been used for some time and has given generally acceptable results. However, the background noise criterion specified for a programme area is a maximum and some new studio areas have been built with noise levels significantly lower. This results in less masking of the interfering sounds which can make the sound insulation inadequate.

Some work on the masking of interfering sound by background noise levels appropriate to studio areas has been carried out and the results have been published.² In addition, a survey was carried out to establish new figures for the peak sound pressure levels generated in a wide range of areas.³ This was originally done to enable the specification for insulation to be updated to allow for the possibility of generally increased levels, particularly in control cubicles, since the original work for Ref. 1 was carried out. The data resulting from this survey also allows the extraction of information on the statistical amplitude distributions of sound pressure levels in a wide range of programme areas.

The object of this report is to combine the information from the work on masking with the results obtained for the amplitude distribution of source sound pressure levels and to produce a statistical forecast of the percentage of time for which given interference criteria will be exceeded. The same insulation design criterion as in Ref. 1 has been assumed, that is, the peak sound pressure level of the interference should just equal the background noise level criterion. From this forecast the additional insulation needed to meet any audibility criterion can be found.

2. Amplitude probability distribution of sound pressure levels

Using the data gathered for Ref. 3, the sound pressure level, in dB (Lin) below the peak value, which was exceeded for x percent of the time (L_x) was extracted for $x = 1, 5, 10, 20, 30$ and 40 for a large number of samples. This data was grouped into programme types and the average value of L_x was obtained for each programme type. The results are given in Table 1, divided into the three categories; music, drama and talks.

Several things are apparent from inspection of Table 1. Firstly, the mean values of the results for 'talks' are statistically indistinguishable from the results for music and so these two categories can be merged. The sample average and standard deviation were calculated for each of $L_1, L_5, \dots, L_{40}$, for the two categories Music/Talk and Drama. Within each of these two categories, the results show a fairly small distribution of values, although the two categories are significantly different from each other. The normalised standard deviations are mostly very similar to each other, showing that the distributions are all of approximately the same type. Finally, the population standard deviations, which are the sample standard deviations corrected for sample size, are also given.

The results thus obtained can be plotted on a graph and, if an arithmetic probability scale is used for the percentage axis, a smooth curve can be drawn through the set of points representing each programme type. This enables intermediate values to be obtained by interpolation. Fig. 1 shows two such curves for the mean values of 'drama' and

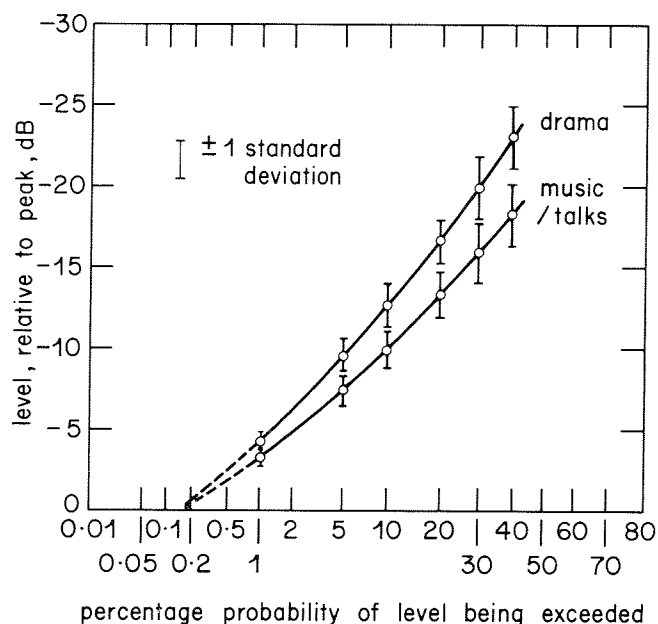


Fig. 1 - Amplitude probability distribution, means

TABLE 1
Source statistics

MUSIC & TALKS

Music

Studio, Continuity pop
Cubicle, Continuity pop
Studio, pop
Cubicle, pop
Studio, light orchestral
Cubicle, light orchestral
Studio, small music
Cubicle, small music
Studio, orchestral music
Cubicle, orchestral music

Talks

Studio
Cubicle

Sample, mean
Sample, standard deviation
Sample, normalised standard deviation
Population, standard deviation

DRAMA

Studio, small drama
Cubicle, small drama
Studio, large drama
Cubicle, large drama

Sample, mean
Sample, standard deviation
Sample, normalised standard deviation
Population, standard deviation

	L_1	L_5	L_{10}	L_{20}	L_{30}	L_{40}
Studio, Continuity pop	4.1	8.4	10.7	13.8	16.3	18.1
Cubicle, Continuity pop	4.2	8.5	11.0	14.0	16.4	18.3
Studio, pop	2.1	5.3	7.3	10.1	12.5	14.6
Cubicle, pop	2.8	6.3	8.7	11.8	14.0	16.3
Studio, light orchestral	3.0	6.9	9.3	12.5	15.7	17.5
Cubicle, light orchestral	3.1	7.0	9.4	12.5	15.1	17.4
Studio, small music	3.5	8.0	10.7	14.6	17.9	20.7
Cubicle, small music	3.5	8.0	10.9	14.6	17.5	20.2
Studio, orchestral music	3.3	7.7	10.6	14.7	17.7	20.5
Cubicle, orchestral music	3.3	7.7	10.6	14.3	17.7	19.8
Studio	3.5	8.0	10.5	13.9	16.4	20.5
Cubicle	3.3	7.0	9.3	12.2	14.4	16.4
Sample, mean	3.31	7.40	9.92	13.25	15.93	18.36
Sample, standard deviation	0.56	0.94	1.13	1.43	1.66	2.00
Sample, normalised standard deviation	0.17	0.13	0.11	0.11	0.10	0.11
Population, standard deviation	0.54	0.90	1.08	1.37	1.59	1.91
Studio, small drama	3.7	8.4	11.4	15.4	18.3	20.7
Cubicle, small drama	3.7	8.1	11.0	14.9	18.2	21.6
Studio, large drama	4.5	10.1	13.1	17.3	20.7	24.3
Cubicle, large drama	4.6	11.0	14.6	18.8	22.7	25.7
Sample, mean	4.13	9.40	12.53	16.60	19.98	23.10
Sample, standard deviation	0.49	1.38	1.66	1.79	2.15	2.32
Sample, normalised standard deviation	0.12	0.15	0.13	0.11	0.11	0.10
Population, standard deviation	0.42	1.20	1.44	1.55	1.86	2.01

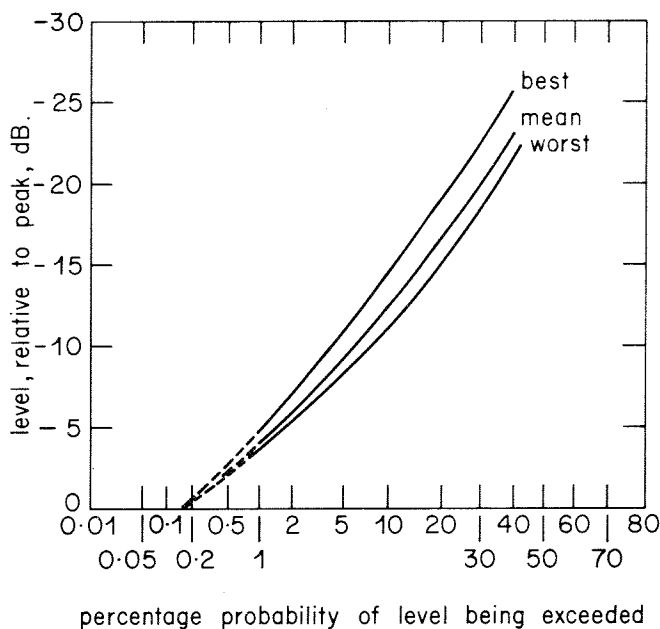


Fig. 2 - Amplitude probability distribution, drama

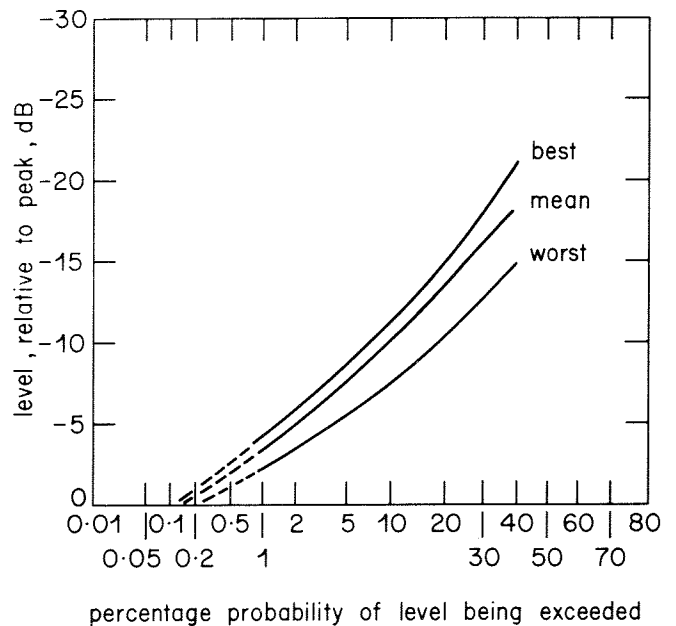


Fig. 3 - Amplitude probability distribution, music/talks

'music/talk' respectively, together with indications of ± 1 standard deviation. Fig. 2 shows a plot of the mean, together with the two extreme cases for the category of 'drama' results. Fig. 3 is a similar plot for the 'music/talk' results. Using these graphs and a knowledge of the sound pressure level (relative to the peak) at which the interference becomes significant the probable percentage of time for which this occurs can be derived.

3. Effects of masking

From Ref. 2 the levels at which particular types of interference become significant can be derived. The measurements of the masking effect of studio background noise were carried out on four different types of material, male speech, pop music, low frequency band-limited noise and high frequency band-limited noise.

The high frequency noise can be eliminated from this discussion because:

- (a) The characteristics of partitions are (normally) such that low frequencies become significant before high frequencies as the interfering level is raised, and
- (b) the masking effect at high frequencies is not more sensitive than at low frequencies (in fact, quite the reverse is true). Thus low frequency effects always predominate.

Table 2 shows the results obtained from Ref. 2 at the three usual background noise criteria (see Fig. 1, Ref. 1) and for three types of interference (low frequency noise is not a realistic interfering signal, but it has been left in this section for completeness). The entries are the mean r.m.s. signal-to-noise ratios in the most critical band of frequency (about 160 Hz) at which the interference first becomes perceptible or disturbing. The Table also gives the difference in level between two signals of which one is just perceptible and the other is just disturbing.

Three interesting features are apparent from these figures. Firstly, for 300 Hz band-limited noise, the critical level of the signal relative to the background noise is independent of the absolute level of the background noise for both the perceptible and the disturbing criteria. Secondly, whereas for programme-type material, the signal level needs to be raised by 5 dB from the just perceptible to give the just disturbing level, the noise signal level has to be raised by 10 dB to give the same effect. This is probably due to the indistinct nature of the noise signal compared with the relatively coherent nature of the programme material. Finally, the critical level of the interfering signal changes by about 8.5 dB for every 10 dB change in the background noise level, at least over the range of background noise levels listed.

Actually, Ref. 2 gives an average figure of 8 dB/10 dB for the two programme-type items. From the results in Ref. 2 Appendix, this ratio is valid for background noise levels down to about -4 dB relative to criterion 'C'. Below this, the levels of background and interference are so close to the threshold of hearing that some distortion of the linear (in dB) relationship occurs such that for a reduction in background noise level of 10 dB from criterion 'C', the interfering signal need only be reduced by about 6 dB to give the same masking effect. In the remainder of this report, however, the ratio of 8 dB/10 dB will be assumed and will give slightly pessimistic results for background noise levels lower than -4 dB relative to criterion 'C'.

The earlier work² was carried out using measurements of mean r.m.s. levels, although even in the report it was stated that it was probably the peak levels which were significant. Therefore, the results presented in Table 2 must be corrected for the peak-to-mean ratios, to conform to the normal practice of specifying peak interference levels.

The approximate peak-to-mean ratios of the material used in the work on masking were about 4 dB for the pop

TABLE 2

Masking levels (mean)

Background Noise Criterion	Material	Interfering Signal-to-Masking Noise Ratio		
		Perceptible	Disturbing	Difference
		dB	dB	dB
C	Speech	-8.5	-3.3	5.2
	Pop	-5.4	+0.3	5.7
	L.F. Noise	-3.0	+7.2	10.2
B	Speech	-9.0	-4.4	4.6
	Pop	-5.8	-0.2	5.6
	L.F. Noise	-2.6	+7.2	9.8
A	Speech	-9.9	-5.0	4.9
	Pop	-6.7	-1.0	5.7
	L.F. Noise	-3.0	+7.0	10.0

TABLE 3

Masking levels (corrected for peak to mean ratio)

Background Noise Criterion	Material	Interfering Signal-to-Masking Noise Ratio		
		Perceptible	Disturbing	Difference
		dB	dB	dB
C	Speech	0.0	+5.2	5.2
	Pop	-1.4	+4.2	5.7
	L.F. Noise	0.0	+10.2	10.2
B	Speech	-0.5	+4.1	4.6
	Pop	-1.8	+3.8	5.6
	L.F. Noise	+0.4	+10.2	9.8
A	Speech	-1.4	+3.5	4.9
	Pop	-2.7	+3.0	5.7
	L.F. Noise	0.0	+10.0	10.0

item and 7 – 10 dB for the speech item. The ratio for 1/3rd octave band filtered noise at 300 Hz has been measured independently and was found to be about 3 dB. Table 3 shows the same results as in Table 2, corrected for peak-to-mean ratios. The corrections used were +4 dB for the pop, +8.5 dB for the speech and +3 dB for the band-limited noise.

4. Calculations of the percentage of time for which the critical levels are exceeded

The probable percentage of the time for which the critical levels of interference will be exceeded can be derived from the data in Sections 2 and 3. The condition assumed is that the installed or theoretical sound insulation reduces the peak level of the interference in the receiving area to be equal to the background noise level criterion for that receiving area in each band of frequencies.

Making the assumptions that the speech and the pop music used in the masking work are representative of the drama and music groups respectively used in Section 2, a chart can be drawn up of the probable percentage of time for which either of the programme types will exceed either of the two audibility criteria, under a number of different conditions. This chart is shown in Table 4. Each entry in Table 4 was obtained by calculating the relevant signal-to-masking noise ratio at which the interference becomes either perceptible or disturbing and using Figs. 1, 2 or 3 as appropriate to find the percentage of the time for which this level is likely to be exceeded.

For the case where the background noise is equal to the criterion, the results from Table 3 for the critical peak levels can be used directly to derive the percentage of time for which the interference is likely to be perceptible or disturbing. Because of the fairly large spread of the programme statistics within each group and the significant effects of the resulting differences, three such percentages

were derived for each condition. These were the mean, the most favourable and the least favourable from each group. This gives some idea of the spread which may be encountered.

For the cases where the background noise was -5 dB and -10 dB relative to the criterion, 4 dB and 8 dB respectively were subtracted from the peak figures given in Table 3 (applying the linear (in dB) 8 dB/10 dB masking results) before the percentages were derived.

5. Results

Table 4 shows that, for the condition where the background noise level is equal to the background noise level criterion specified for any receiving area, the worst-case interference will probably exceed the perceptible level for 1.4% of the time and is not likely ever to be disturbing. This result occurs when the source of the interference is the 'worst' example of the music measurements and the relevant receiving area background noise criterion is 'A'. Using Fig. 3, this percentage can be interpreted as a sound pressure level 2.7 dB below the peak sound pressure level. This can be reduced to zero by improving the sound insulation by 2.7 dB.

In a similar way, any result from Table 4 can be reduced to any required percentage by using Figs. 1, 2 and 3 as appropriate to find the necessary additional sound insulation. Appendix 1 gives some worked examples.

A table similar to Table 4 can thus be derived showing the additional insulation required for each set of conditions to reduce the level of interference to any perceptibility criterion.

For example, Table 5 shows such a table of extra insulation, relative to that predicted by equating the peak level of the interference to the relevant background noise

TABLE 4

Percentage of time of audible interference for various conditions, with the sound insulation calculated for peak interference equal to the criterion background noise levels

Background Noise Level, Relative to Criterion (dB)	Background Noise Level Criterion	INTERFERENCE SOURCE											
		SPEECH						MUSIC					
		Perceptible			Disturbing *1			Perceptible			Disturbing *1		
		Best *2	Mean *3	Worst *4	Best *2	Mean *3	Worst *4	Best *2	Mean *3	Worst *4	Best *2	Mean *3	Worst *4
0	C	0.15	0.15 *7	0.15	0	0 *6	0	0.3	0.4	0.6	0	0	0
	B	0.20	0.20	0.20	0	0	0	0.35	0.5	0.8	0	0	0
	A	0.20	0.30	0.35	0	0	0	0.5	0.7	1.4	0	0	0
-5	C	0.75	1.0	1.2	0	0	0	1.8	2.6	5.0	0	0	0
	B	0.9	1.2	1.4	0	0	0	2.1	3.0	6.0	0.15	0.15	0.25
	A	1.2	1.6	2.0	0.2	0.2	0.2	2.7	4.0	8.5	0.2	0.3	0.45
-10	C *5	2.4	3.5	4.5	0.5	0.6	0.7	6.5	9.0	17.0	0.9	1.3	2.6
	B	2.8	4.0	5.2	0.75	0.95	1.1	7.5	10.0	19.0	1.1	1.5	3.0
	A	3.5	5.0	6.6	0.9	1.2	1.4	9.0	12.0	22.0	1.5	2.1	4.2

* NOTES

1. 'Disturbing' is defined (in Ref. 2) as that level which would just disturb a performer waiting to do his part in a production.
2. 'Best' refers to the most favourable statistical amplitude distribution of sound pressure levels in that group of distributions of the same source type.
3. 'Mean' refers to the average statistical amplitude distribution of sound pressure levels for the whole group of the same source type.
4. 'Worst' refers to the least favourable statistical amplitude distribution of sound pressure levels in that group of distributions of the same source type.
5. -10 dB relative to criterion 'C' is very close to the threshold of hearing and so the linear masking function of 8 dB of masking for 10 dB change in background noise is not likely to be applicable. At this level, the masking effect is about 5 or 6 dB per 10 dB change in background noise level. The figures given are therefore pessimistic.
6. Percentages less than, or equal to 0.1% are entered as 0.
7. Percentages less than 1.0% have been obtained by extrapolation of the available statistical information and are not reliable. The available data appears to show that peak sound pressure levels which occurred for less than 0.15% of the time were missed altogether by the measuring equipment.

TABLE 5

Extra sound insulation required to reduce the interference to be perceptible for only 1% of the time

Background Noise Relative to Criterion dB	Background Noise Criterion	INTERFERENCE SOURCE					
		Speech			Music		
		Best dB	Mean dB	Worst dB	Best dB	Mean dB	Worst dB
0	C	—	—	—	—	—	—
	B	—	—	—	—	—	—
	A	—	—	—	—	—	0.5
-5	C	—	—	0.3	1.3	2.0	3.2
	B	—	0.5	0.8	1.7	2.4	3.6
	A	0.7	1.4	1.7	2.6	3.3	4.5
-10	C	3.3	4.0	4.3	5.3	6.0	7.2
	B	3.8	4.4	4.8	5.7	6.4	7.6
	A	4.7	5.3	5.7	6.6	7.3	8.5

criterion in each frequency band, as is required to reduce the interference to a level at which it is perceptible for 1% of the time.

Table 6 shows the extra insulation relative to that predicted by equating the peak level of the interference to the relevant background noise criterion in each frequency band, required to reduce the level of the interference to that at which it is not perceptible at any time. This level is a function of the absolute signal-to-noise ratio and the masking effect only and does not depend on the signal statistics. It is derived from the results in Table 3, corrected for the 8 dB per 10 dB masking correction.

TABLE 6

Extra insulation required to reduce the interference to be imperceptible

Background noise Relative to Criterion dB	Background Noise Criterion	Interference source	
		Speech	Music
0	C	0	1.4
	B	0.5	1.8
	A	1.4	2.7
-5	C	4.0	5.4
	B	4.5	5.8
	A	5.4	6.7
-10	C	8.0	9.4
	B	8.5	9.8
	A	9.4	10.7

Comparison of Tables 5 and 6 shows that the extra insulation required to reduce the percentage of time for which the interference is perceptible from 1 percent to zero is between 2.2 dB and 4.7 dB depending on the conditions.

6. Conclusions

The method of calculating sound insulation requirements between programme areas used in Reference 1, that

is, equating the interference via the partition to the receiving area background noise criterion has been shown to be adequate (to within 0.5 dB) in those cases where the actual background noise level is equal to the relevant criterion. However, in those cases where the receiving area is less noisy than its' criterion, this method can produce errors equivalent to as much as 4.5 dB where the background noise is 5 dB lower than the criterion, and as much as 8.5 dB where the background noise is 10 dB lower than the criterion (assuming that the interference is acceptable if it is perceptible for only 1% of the time).

The method used to obtain these results is sensitive to small changes and errors of the order of ± 1 dB, which could easily arise in the measurement of a partition sound pressure level difference, will make a significant difference to the percentage of the time for which the interference is perceptible. In particular, it is thought that the difference between the results for speech and music might be attributed to a small error (≈ 1.3 dB) in the measurement of the peak-to-mean ratios rather than any fundamental difference between the two types of material.

As a general guide to the design of partitions, the results show that criterion 'A' areas (those with the highest permitted background noise) are more sensitive to interference than criterion 'C' areas in those cases where the achieved background noise is significantly less than the criterion.

7. References

1. SMITH, T.J.B. and GILFORD, C.L.S. 1968. Airborne sound insulation requirements in studio centres. BBC Research Department Report No. PH-21, Serial No. 1968/35.
2. ROBINSON, A.P. 1978. The masking effect of background noise. BBC Research Department Report No. 1978/3.
3. MEARES, D.J. Statistics of typical programme sound pressure levels in sound studios and their control rooms. BBC Research Department Report No. 1973/37.

Appendix 1

Worked Examples

Taking as an example the entry in Table 4 for music, criterion 'A', background noise level -10 dB relative to the criterion. The table entry reads:

9 ; 12 ; 22 ; 1.5 ; 2.1 ; 4.2

Several examples, based on this entry, are calculated using Fig. 3.

- (a) To reduce the percentage interference time of the mean perceptible result from 12% to 1%

$$\left. \begin{array}{l} 12\% \equiv -10.7 \text{ dB} \\ 1\% \equiv -3.3 \text{ dB} \end{array} \right\} \text{ From Fig. 3}$$

Hence 7.4 dB of extra sound insulation is required.

- (b) To reduce the 'worst disturbing' result to just 'not

disturbing'. Disturbing level is exceeded for 4.2% of the time.

$$4.2\% \equiv -5.0 \text{ dB}$$

Hence 5.0 dB of extra sound insulation is required.

- (c) To reduce the 'worst perceptible' result to 'just not perceptible'. Perceptible level is exceeded for 22% of the time.

$$22\% \equiv -10.7 \text{ dB}$$

Hence 10.7 dB of extra sound insulation is required.

Note that the difference between 'perceptible' and 'disturbing' for this class is 5.7 dB (from Table 2). Adding 5.7 dB to result 'B' (5 dB) gives the same 10.7 dB required to reduce this example to just 'not perceptible'.